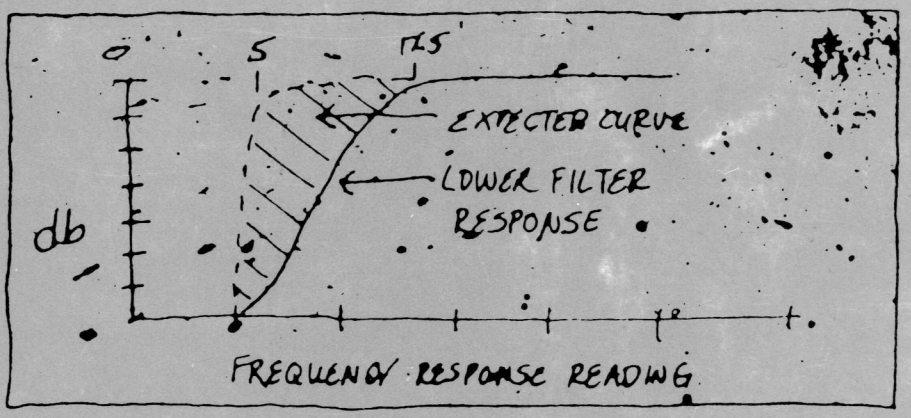
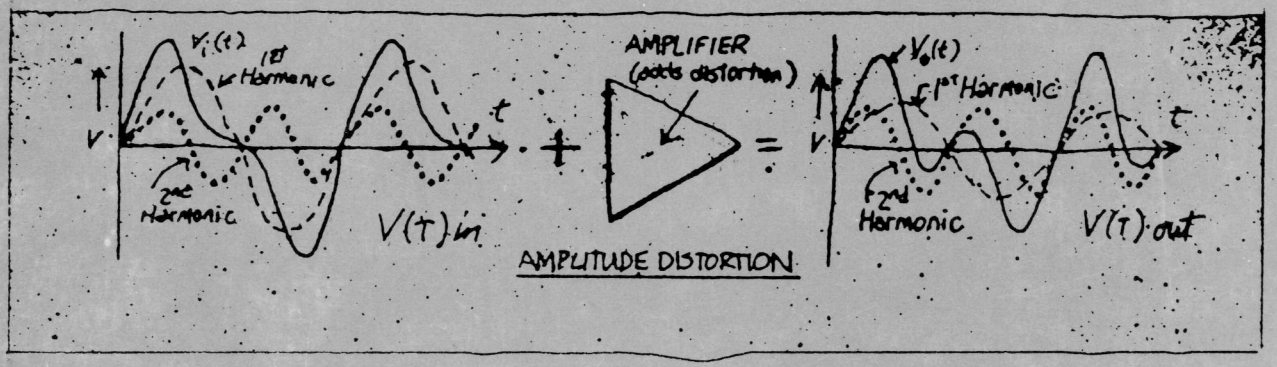
WAVETEK

TESTING BROADBAND LAN PERFORMANCE





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Wavetek is the leading supplier of broadband communications test equipment. To find out more about the equipment mentioned in this manual, call your nearest Wavetek sales representative, or our factory sales team.

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BROADBAND LOCAL AREA NETWORK

Broadband Local Area Networks (LAN) offer many advantages over other approaches to data transmission. With up to 450MHz of bandwidth available, a broadband local area network offers the capability of supporting video, audio and data communications simultaneously. A broadband network can cover a wide geographic area, can support a large number of users, and is easily expandable.

Broadband networks have proven to be the superior choice in many applications. Campus networks require the versatility of broadband to transmit video, audio, and data throughout the system. Government installations rely on the demonstrated dependability of broadband. And in industrial applications, broadband is an effective and efficient medium for providing plant automation, security, energy management and administration functions.

Broadband LANs are easily maintained. LAN maintenance and test equipment is easy to use, reliable, and accurate. Test equipment enables the LAN operator to maintain a high quality, dependable LAN system.

This manual will show in a series of straightforward, easy to understand procedures, what is required to certify and maintain a broadband LAN. Each procedure will describe the test, the equipment needed, how to perform the test, and how to analyze the results of the test.

SYSTEM FREQUENCY RESPONSE

Test Definition:

The system frequency response measurement is the determination of component of system RF amplitude transfer characteristics as a function of frequency. In RF local area networks, this test is used to align and verify amplifier and passive component frequency response. The test results also inform the technician about:

*System Flatness
*Incorrect Component Placement
*Defective Components
*Loop Loss
*Signal Reflection (impedance match characteristics)

The system frequency response measurement is a valuable tool that may be used to certify new system performance and used as a diagnostic aid in a preventive maintenance program

Test Equipment:

Three basic methods for determining frequency response are available to the system operator. Each involves a "sweep and recovery" technique. The selection of the proper technique and the proper sweep/recovery test equipment should be based on the characteristics of the system to be tested. The major determining criteria are dictated by the system:

*Frequency Resolution
*Amplitude Sensitivity
*Ability to Handle High Level Transients
*Bandwidth
*Availability of Space in the Spectrum to Insert a Pilot Carrier

The three sweep/recovery techniques for system frequency response measurements are:

*Low-level synchronous (tracking) sweep
*Low-level asynchronous sweep
*High-level synchronous sweep

The low-level synchronous sweep approach uses a low level tracking analyzer. The advantage of this technique is that the sweep stimulus is inserted 10 to 30dB below the system carriers. This typically produces less system interference than the two other measurement approaches. The disadvantages of this approach are that there is a loss in resolution due to noise-bandwidth characteristics and the technique requires a phase-locking pilot reference which may be inconvenient during signal return alignment (recovery).

Use of the low-level asynchronous sweep/recovery test system is very common in the industry. This test does not require a dedicated sweep/recovery system or the use of special pilots. To initiate the test, the operator connects a sweep generator (Wavetek Model TD-1 or 1801C) at the appropriate system test point. (The outbound and inbound legs of the LAN are tested individually.) The operator then connects a conventional spectrum analyzer (Wavetek Model 1880 or 1881) at the appropriate test point to recover the sweep. Center frequency and span settings are adjusted to match the band to be measured. Sweep recovery is accomplished by asynchronous (non-phase-locked) detection of the sweeping carrier.

CAUTION

Because the sweep generator and spectrum analyzer are continuously changing in frequency, scan loss may occur. To avoid this problem, measure the sweep amplitude in the CW mode first, then verify that the detected sweep amplitude matches this CW reference. Adjustments to the sweep time on the generator may be necessary.

Use a spectrum analyzer that has a long persistance phosphor CRT or use an analyzer with a peak hold function (Wavetek Model 1880 or 1881 System Analyzer) to make it easier to analyze the test results.

The high-level synchronous sweep measurement technique has the advantages of superior resolution and accuracy. The sweep carrier is typically inserted at 10 to 15dB above the system carrier level, producing substantially better signal-to-noise performance upon detection. This method uses a "broadband" detector as opposed to the "narrow-band" instruments used in the tests detailed earlier. The use of broadband technology is important because it is inherently easier to design and manufacture a precision broadband detector than to design and manufacture a precision multi-octave mixer network (such as the narrow band circuitry used in spectrum analyzers).

The disadvantage of using high-level sweep energy is that it may increase bit error rates. Because the energy of the sweeping carrier is substantially higher than any system carrier, data destroying collisions may occur causing the need for regeneration of some data bits. CSMA/CD systems generally are designed to be tolerant of this problem because it may occur naturally in this system format. Optional filters may be used to protect specific bands from high-level sweep energy interference.

Test Procedure:

Regardless of the technique used, the operator should first verify the "back-to-back" performance of the sweep/recovery test set. The back-to-back performance of a test set is simply the performance of the set when no elements are in the circuit

between the set's transmitter and receiver units. Connect the transmitter to the receiver with a short coax cable as shown in Figure 1-1.

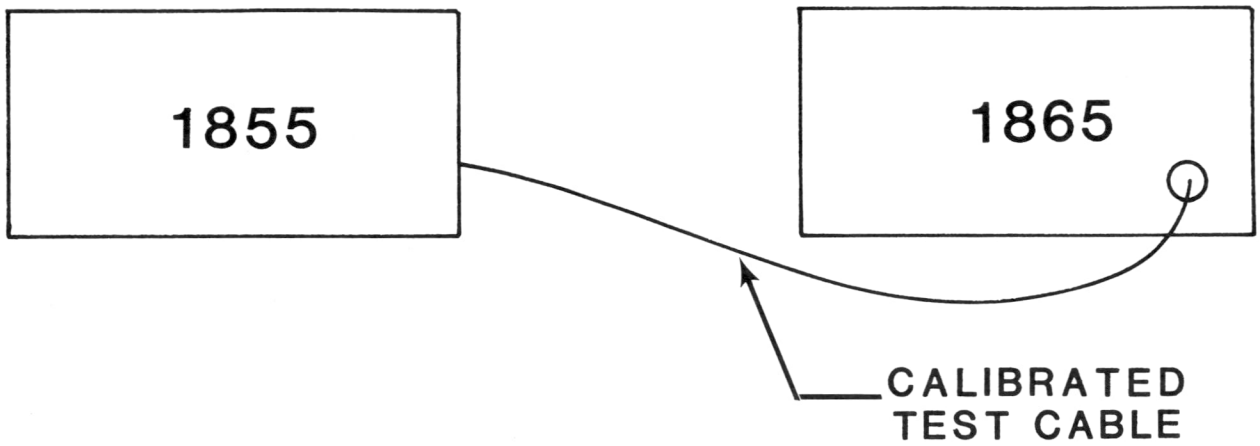


Figure 1-1. Back-to-Back Connection

Set the transmitter sweep parameters slightly greater than the system band to be examined. The RF output level also should be adjusted to the required insertion level (this will be discussed in detail later in the procedure). Verify that the transmitter is sweeping through the proper frequency range and that the transmitter to receiver signal is sufficiently flat.

Figure 1-2 shows the flatness in the frequency response from a typical back-to-back performance test. As the transmitter frequency sweeps from F1 (the initial, low end frequency) to F2 (the final, high end frequency) the receiver trace level will vary. The peak-to-valley measurement across the top of the received (recovered) signal must be within the range specified for the test set. That specification is indicated as 0.50dB for the "typical" test set results shown in Figure 1-2.

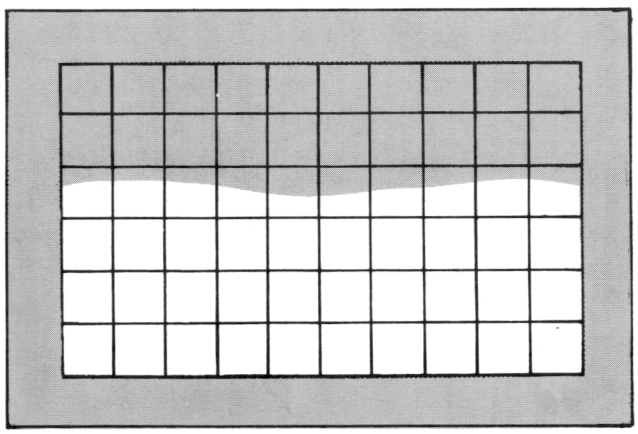


Figure 1-2. Back-to-Back Performance Test

Other performance verification procedures may be needed, depending upon the particular test equipment. The operator should carefully read the operations manual for the test equipment before starting the field test.

When the performance verification is completed, the operator can begin the system frequency response measurement. The transmitter should be connected to the headend test point as shown in Figure 1-3 to monitor the outbound (forward) response.

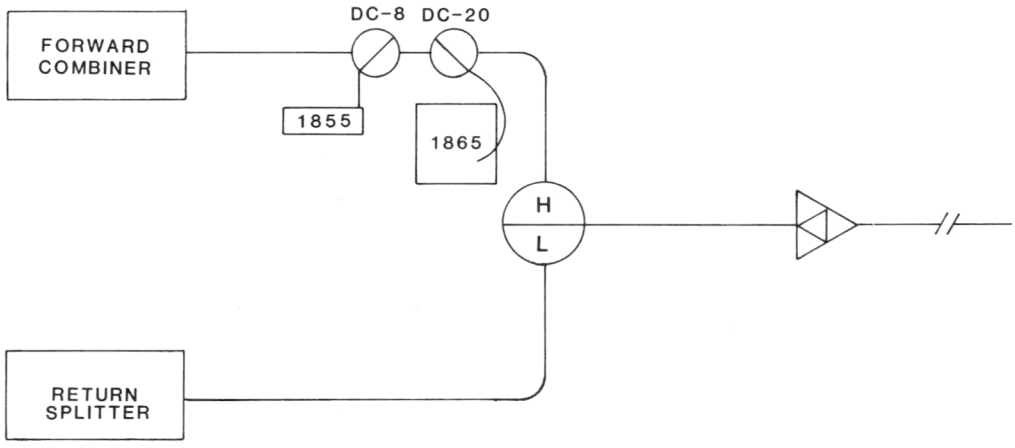


Figure 1-3. Outbound Test Set-Up

The insertion directional coupler is used to "program" the desired sweep level. In this example, the tap loss is 8dB. The sweep system will have a system level range of 42 to 52dBmV. If the head end levels, after combining, were 35dBmV, a setting of 58dBmV on the transmitter would produce the required level for system sweeping (58dBmV - 8dB tap loss - 35dBmV data carrier levels = 15dB sweep to carrier ratio). The test directional coupler, typically a 20dB test point, allows inspection of the sweep after it is "mixed" with the system and provides minimum loss in outbound transmission. The operator should examine this response to verify simultaneous triggering of the transmitter and receiver units and to compensate for losses introduced by test cables.

After verification, the receiver is ready for field operation. Connect the unit to the first amplifier input test point. Verify for desired input response, as predicted by design.

Next, connect the receiver to the amplifier output test point. Evaluate the response and adjust the amplifier to produce the required frequency response. Refer to the operations manual for specific instrument operation. The output should be examined for:

*Response Characteristics
*Signature Buildup
*Standing Waves

Response characteristics are the overall bandwidth characteristics to include the lower and higher filter roll-off points. This verifies that the cascade will amplify the desired band and disregard spectrum where amplification is not desired (Figure 1-4).

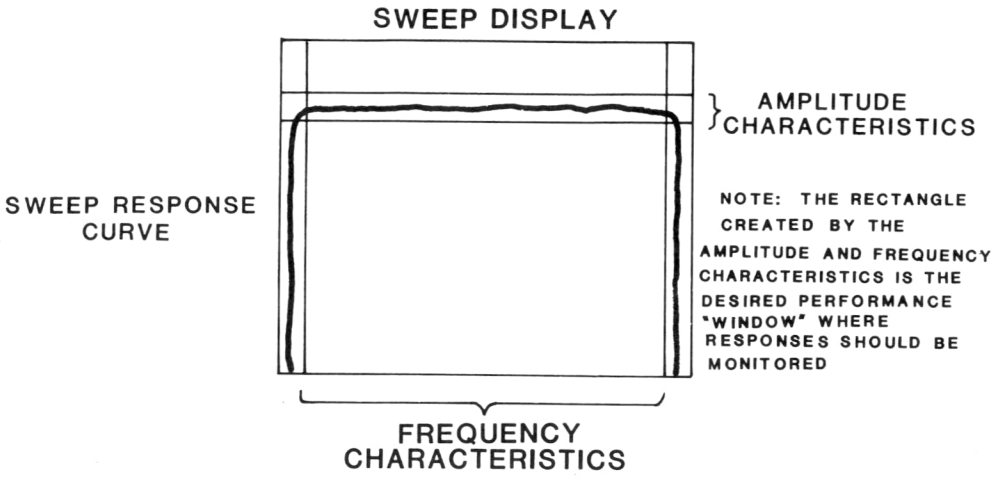


Figure 1-4. Response Characteristics

Signature buildup is an incremental "extra" contribution to gain in a particular portion of the operation spectrum (Figure 1-5).

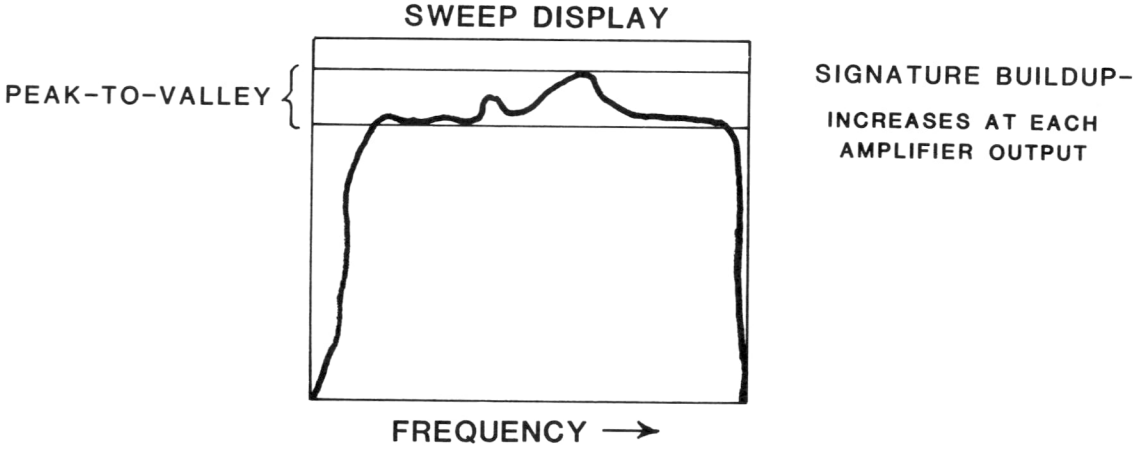


Figure 1-5. Signature Build-Up

These signature "bumps" may be quite small per amplifier, but will grow in cascaded amplifiers. Consult the operating manual of the amplifier for corrective procedures, if needed.

Standing waves are the result of impedance mismatches located outbound of the amplifier (Figure 1-6).

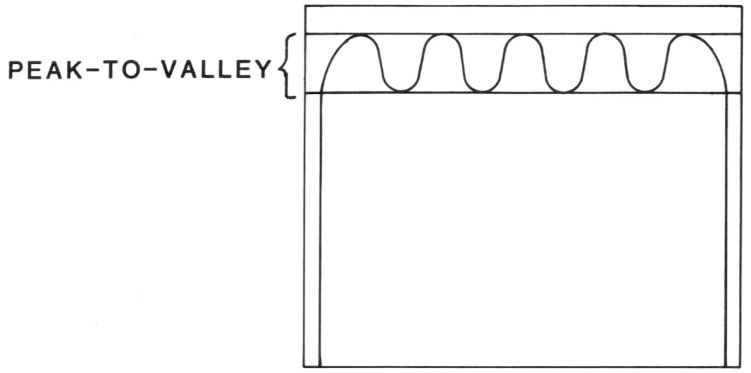


Figure 1-6. Standing Waves

The majority of the amplifiers used in broadband systems use test points which exhibit little to no isolation of reflections. This allows the operator to display the output response of the amplifier and the reflected energy from a system fault (Figure 1-7).

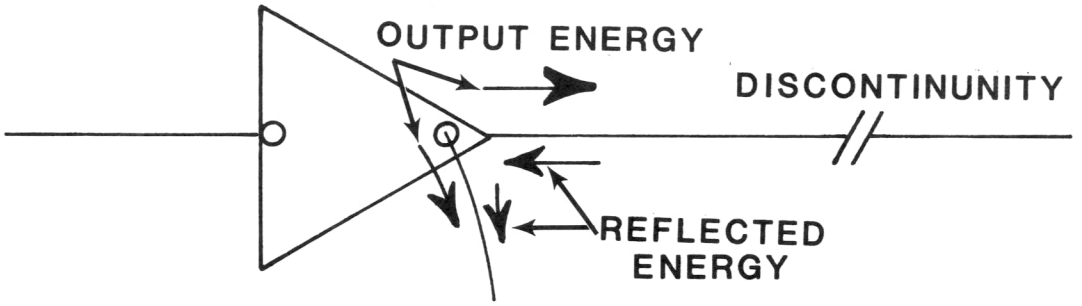
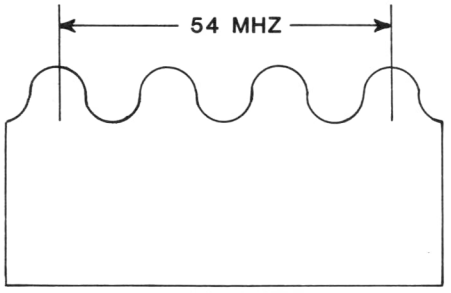


Figure 1-7. Amplifier Test Point

The standing waves may be useful in determining the distance to a defective component or system fault (Figure 1-8).



ONE CYCLE = 18.0 MHz
.750 FOAM VP = 93%
492 X .93 = 457.56 = 25.42 FEET
18

$$\frac{492 \times VP}{F}$$

VP = Velocity of propagation

F = Frequency of 1 cycle in MHz

Figure 1-8. Standing Wave Calculation of Distance to Fault

In any case, the problem should be corrected before sweep efforts are continued.

Return sweeping requires similar examination, but the technique is different. In this case, the operator is sweeping "to" a point, instead of "away" from a point, as in the outbound. Two approaches are available; one requiring the movement of the sweep source; the other moves the receiver (Figure 1-9).

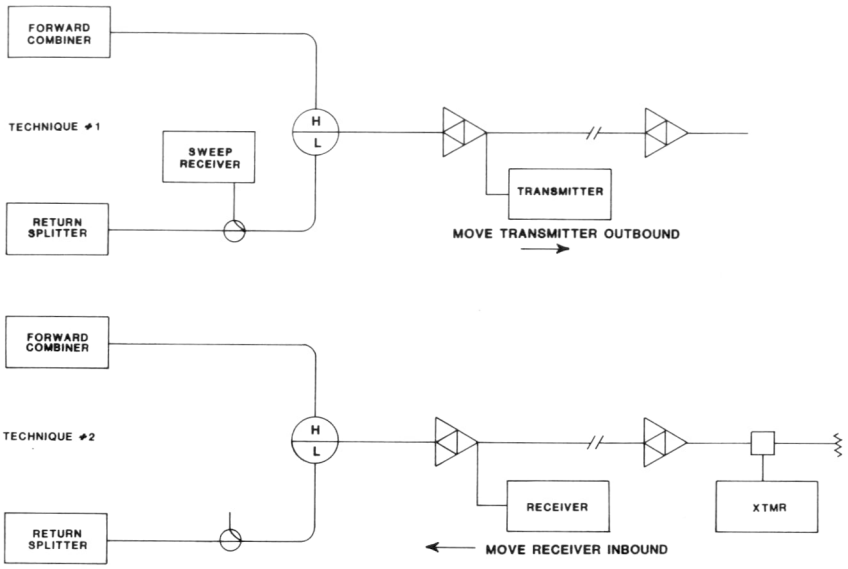


Figure 1-9. Return Sweep Technique

In either case, the sweep operator is adjusting an amplifier to a receive point, which requires some provision for correction feedback. This may involve a second technician, or a camera and outbound modulator to return the results.

GROUP DELAY

Test Definition:

Two forms of transmission delay exist in modern broadband RF networks; absolute delay and relative group delay. Absolute delay is rarely a problem with most transmission formats, as it is typically a flat delay throughout the band. Its main contributor is the velocity of propagation figure for the cable and small amounts of transfer delay in line amplifiers. Relative group delay, on the other hand, could have severe effects, especially when added to other distortion components, such as hum, carrier-to-noise relationships, and inter-modulation products.

Relative group delay is differential delay with respect to frequency in a band of interest (typically over the -1dB points). High speed, single channel formats may suffer this distortion during demodulation of the original signal. As sideband components may be arriving at different times respective of their instantaneous modulation times, inter-symbol crosstalk or smearing may occur, destroying the information.

Group delay occurs when B (phase-shift coefficient) is not proportional to $W(2\pi f)$ over a specific band in frequency. For wave motion, a general relationship exists among frequency, wavelength, and phase velocity:

$V_P = \lambda f$
Where V_P = phase velocity
λ = wavelength
f = frequency

The phase-shift coefficient is the phase shift per unit length, and considering a phase shift of 2 radians over a distance of one wavelength:

$$B = \frac{2\pi}{\lambda} \quad \text{or} \quad \lambda = \frac{2\pi}{B}$$

Substitutions allow the replacement of the V_P formula previously stated to equal the new equation:

$V_P = W/B$
Where V_P = phase velocity
$W = 2\pi f$
B = phase shift coefficient

This argument states that the phase velocity will remain constant while B is proportional to W. The transmission system adhering to this prediction would be free of phase distortion, as all components making up the original signal would be transmitted and received at the same velocity.

In real world systems, some phase distortion will occur. Main contributors to group (or phase) delay are translators, structural return loss in cable, and other filter related components. The general unit of measure for group delay is

$$\frac{\Delta T}{\Delta F} \text{ or } \frac{\text{nanoseconds}}{BW}$$

Test Equipment:

The Wavetek Group Delay test set is an instrument which compares the phase relationship of a reference signal with the demodulated signal which has passed through the unit under test. See Figure 2-1.

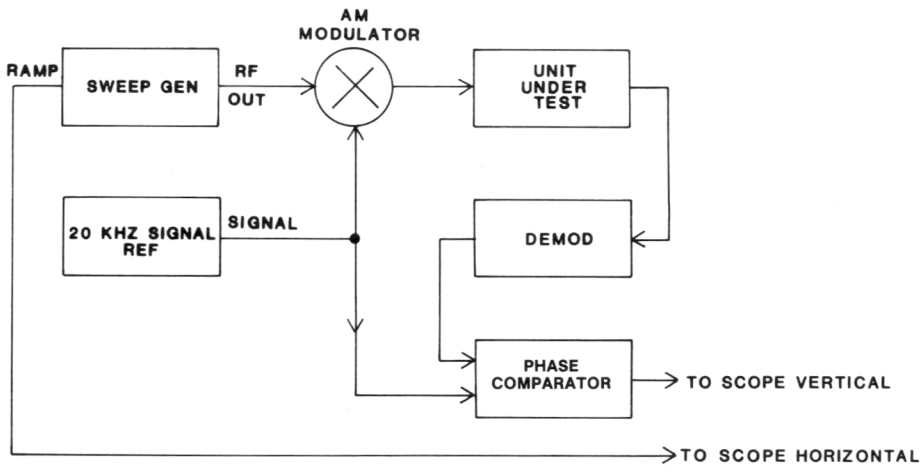


Figure 2-1. Block Diagram of Group Delay Analyzer Test Set

In this diagram, the sweep generator's carrier is AM modulated with a 20kHz tone. This test signal is passed through the system and recovered by the demodulator. The remaining signal is phase compared with the reference signal for a resultant phase comparison relative to frequency.

Test Procedure:

To measure group delay, set up the equipment as illustrated in Figure 2-2. Connect the step attenuator (Wavetek Model 7580) as shown, with the attenuator settings adjusted to match the system loop-loss. Perform the test as directed in the operating manual, with the sweep generator (Wavetek Model 1080) center frequency set at a frequency in the downstream band (F_2), and a sweep span a few MHz greater than the -1dB response of the translator. Verify the amplifier (Wavetek Model PA20) group delay response.

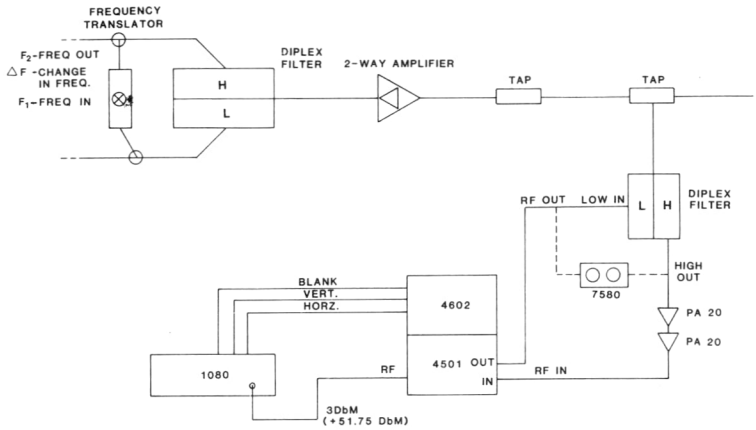


Figure 2-2. Group Delay Set-Up

NOTE: The diplex filter should be verified prior to use to assure minimum group delay at the test operating frequencies.

After the test set has been calibrated and verified, connect the RF out to the low pass of the diplex filter. The common output should be connected to the line tap for RF insertion. The high out of the filter should be connected to the input of the amplifiers (Wavetek Model PA20) with the output of the amps connected to the RF in on the group delay analyzer (Wavetek Model 4501). Set the sweep generator (Wavetek Model 1080) to F_1, the translator's input center frequency and span.

NOTE: If greater isolation is needed due to poor diplex filter response, the unit may be connected as illustrated in Figure 2-3.

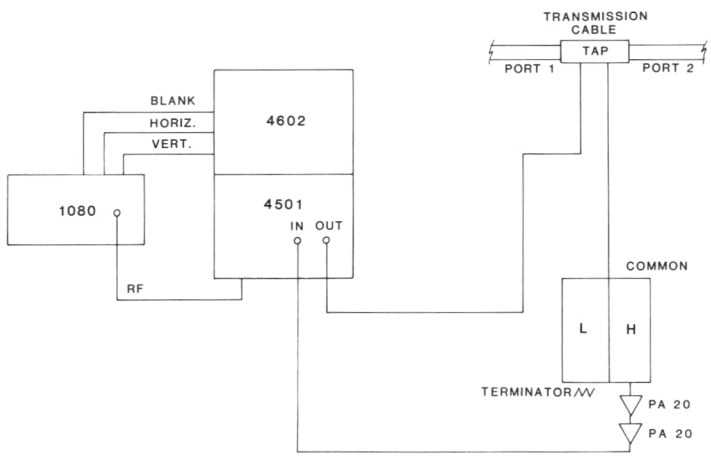


Figure 2-3.. Alternate Set-Up Connection

This will add isolation in the form of tap directivity, roughly 35dB.

NOTE: The amplifiers are used to compensate for the data network's loop loss (typically 45dB) with the group delay anlayzer having an operational window of + 10 to -20dB RF out to RF in. It may be necessary to introduce a third amplifier and the step attenuator (Wavetek Model 7580) in the test loop to balance the output to input as close to 0dB as possible. In any case, noise on the group delay trace is an indicator of lack of recovery gain while no delay response could be an indicator of an input level that is too high, causing gain compression.

Perform the test as defined in the operations manual. Trial and error techniques have shown that 25ns/div vertically produce very clean results. Remember that the frequency change of the translator must be added to the markers for accurate frequency information.

Figure 2-4 is a typical response taken from a system. Group delay measures approximately 110ns which is considered marginal.

Instrument
Settings:
Group Delay Sensitivity - 25ns/div
Sweep Span - 7MHz
F_O - 267MHz

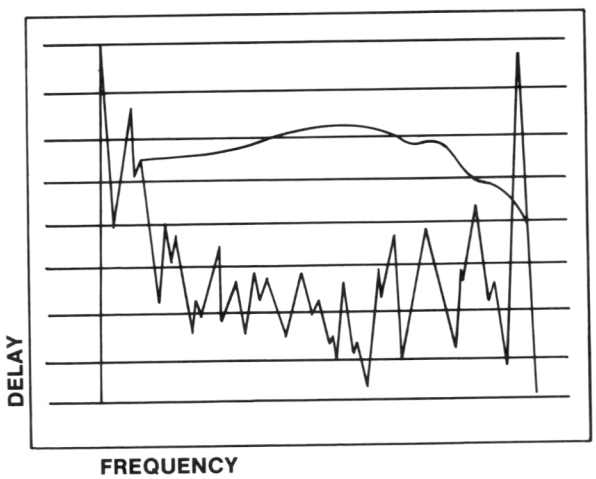


Figure 2-4. Group Delay Response

NOTE: The Wavetek Group Delay Analyzer Model 4501 has limited offset capabilities (11 μ s). This will limit its measurement range out into the system to approximately 4900 feet. The distance from the translator may be calculated using the following formula:

$$L(ft) = 11\,\mu s - \frac{\text{translator delay } (\mu s)}{2} * 985ft/\mu s * VP$$

CARRIER-TO-NOISE MEASUREMENTS

Test Definition:

Carrier-to-noise is a measurement of a carrier, at its desired transmission level relative to the noise power contributed by the line amplification equipment. This figure is a component of, but not the total contributor to, the carrier's received signal-to-noise ratio.

The measurement is needed because line amplifiers add a fixed amount of noise to the desired signal each time it is reamplified to compensate for losses. This noise level may be predicted readily, if the line amplifiers are operated within the unity-gain concept. For the cascade noise figure; NL=NF+10 Log N

Where: NL = Cascade noise figure in dB
NF = Noise figure of the amplifiers in dB relative to the 4MHz bandwidth
N = number of identically operated amplifiers with the same noise figure

Simple mathematics will show that the noise level will increase 3dB each time the number of amplifiers is doubled, a useful troubleshooting rule.

Test Equipment:

The test instrumentation needed to measure carrier-to-noise should have corrections for reading the noise amplitude. The Wavetek SAM series signal level meters (excluding the SAM Jr.) and the Wavetek Model 1880 and 1881 system analyzers have built in provisions for C/N readings, requiring no charts or tables.

Test Procedure:

To measure the carrier-to-noise ratio on the system, inject test carriers at system levels near the low and high ends of the operational spectrum. With a signal level meter (Wavetek SAM series) or spectrum analyzer (Wavetek Model 1880 or 1881), read and record the received carrier level. Remove the carrier or tune the test instrument slightly off frequency. Read the level of noise remaining.

Refer to the test equipment operating manual to secure the corrected noise level. The standard noise level measurement is referenced to a 4MHz received bandwidth. The operating manual will give corrections for bandwidth conversions, peak to effective noise level, and impulse noise figures.

When the measurement is made with an analyzer, verify that the system noise is sufficiently higher than the instrument noise, by increasing the input attenuation

1dB. The displayed noise level should decrease by 1dB and the carrier-to-noise relationship should remain constant. If this relationship changes, preamplification and preselection will be needed to perform the test.

The corrected noise level should then be subtracted from the reference carrier level to calculate the measurement value in dB. This process should be repeated at each test frequency. Results of the test should be compared to design specification for compliance.

$$C/N = CL - NL + 10 \text{ Log } \frac{4MHz}{BW} - IB - PD$$

WHERE:
CL = Carrier Level
NL = Apparent Noise Level
BW = Resolution Bandwidth of Instrument
IB = Impulse Bandwidth Correction Factor of Instrument
PD = Peak Detector Correction Factor of Instrument

The Wavetek SAM I, SAM III, 1880, and 1881 have built in correction factors for BW, IB, & PD.

$\therefore$ C/N = CL - NL

Other instruments require the use of the previous formula.

HUM MODULATION

Test Definition:

Hum modulation is defined as the low frequency modulation of a carrier when passing through an active or passive component of a transmission system. This problem is typically traceable to power supply filter failures in line amplifiers yielding a 120Hz ripple modulation source or 60Hz halfwave rectification in passive devices due to improper solder connections or oxidized connectors. Excessive amounts of hum modulation can increase bit-error rates due to demodulation distortion of the data carrier. Figure 4-1 illustrates the effects of hum modulation on a carrier.

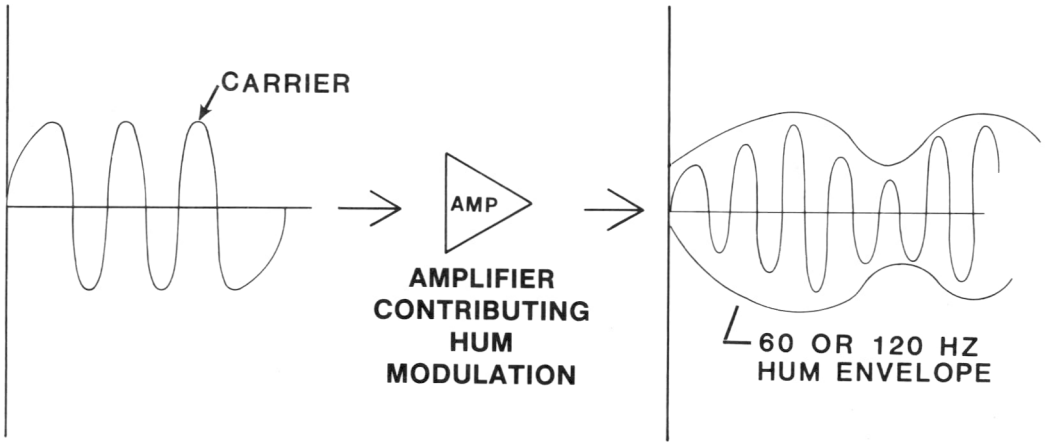


Figure 4-1. Hum Modulation

Test Equipment:

The simplest way to test for hum modulation is to use a signal level meter equipped with hum detection circuitry. The Wavetek SAM series meters (except the SAM JR) have provisions for hum readings and are very easy to use.

Test Procedure:

To perform the test, inject a CW carrier at system levels at the headend. Assure that this CW carrier is free of hum from the instrument which produces it. Proceed to the remote test point and connect the meter to the system. Tune the instrument to the test carrier and select hum function on the meter. Percentage of hum modulation will be displayed directly on the meter movement.

As hum modulation is a quick and easy test to perform, it should be incorporated into normal preventive maintenance testing procedures. Refer to the acceptance criteria for the specific maximum value of hum allowed on the system.

INTERMODULATION

Test Definition:

Nearly all serious distortions associated with transmission on broadband coaxial systems are caused by the active equipment in the transmission medium. These distortions may be divided into two major categories: 1) non-linear distortions (i.e. harmonic, intermodulation, cross-modulation), 2) linear distortions (i.e. amplitude vs. frequency and phase vs. frequency). The latter is caused by inductance and capacitance characteristics and is typically measured by sweep frequency analysis and relative group delay testing, respectively. Non-linear distortions, the more complex functions of the transfer characteristics of amplification equipment, are the primary topic of the discussion.

To better understand this concept, a basic review of amplification is in order. The ideal amplifier would have an input to output relationship predicted by the linear function y=mx+b, where:

y = out level
x = input level
m = AC gain
b = DC offset or output level

The DC variable (b) is normally not considered in frequency amplification devices and should be considered as "0". This would leave the simplified expression y=mx or Eout=A x Ein. (See Figure 5-1).

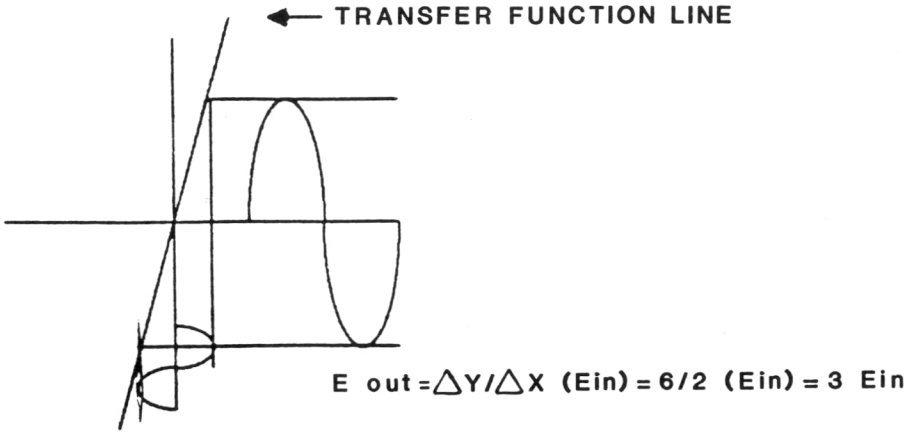


Figure 5-1. Linear Amplifier Response (Time Domain)

In this figure, the output level is predicted by the slope of the transfer function line multiplied by the input level. This produces amplification to the input signal with no distortion.

"Real world" amplifiers have more complex transfer function lines than the linear response of Figure 5-1. An example of this phenomenon may be best understood by the graphic expression of both second and third order distortion.

Second order distortion occurs when amplification equipment is operated with a quiesent point closer to cut-off or saturation. When this condition exists, amplification occurs similar to the square law function of diodes (Figure 5-2). The output frequency content may now be predicted by the expression Eout-AEin=(BEin)^2.

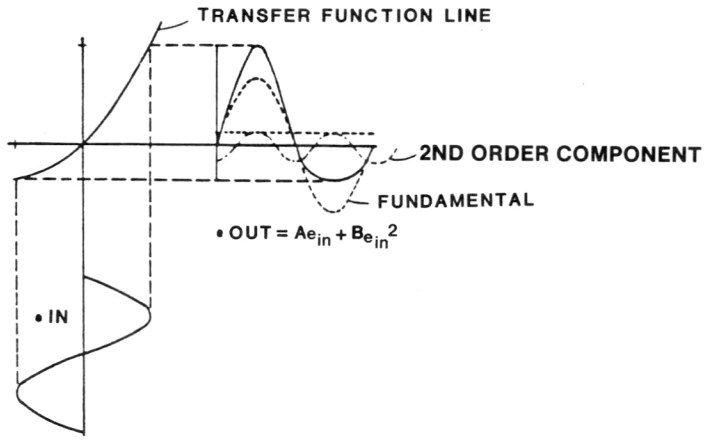


Figure 5-2. 2nd Order Distortion (Time Domain)

One technique of accounting for this change in output level with respect to the input signal would be Fourier Analysis. This mathematical expression allows for the description of a periodic signal, in terms of its fundamental frequency component and frequency components, at integer multiples of the input signal. In simple terms, the output of the amplifier will contain the amplified original signal *and* a component at twice the input frequency. Examine the graphic representation in the frequency domain (Figure 5-3).

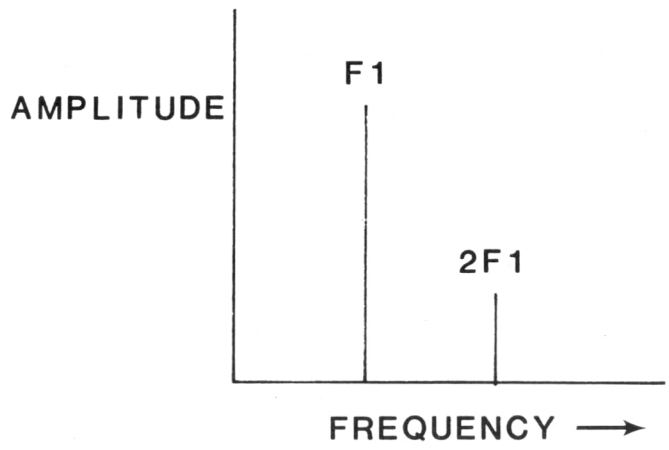


Figure 5-3. 2nd Order Harmonic Distortion (Frequency Domain)

This transfer function will also allow the mixing of two (2) fundamental carriers to produce new components at the sum and difference of the original frequencies. (Figures 5-4).

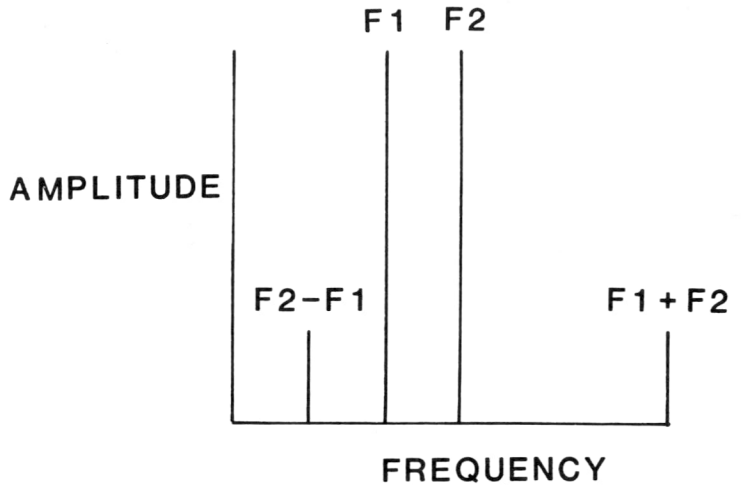


Figure 5-4. 2nd Order Intermodulation (Frequency Domain)

Applying this theory to multi-frequency transmission systems, the components of second order distortion may fall in frequency on or about the operating spectrum of a modulated carrier, causing distortion during demodulation. (Figure 5-5).

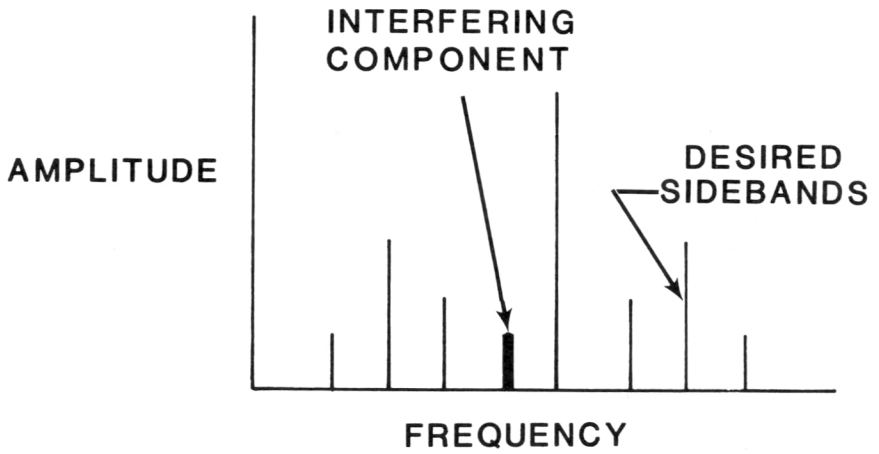


Figure 5-5. Interfering Beat

Second order distortion became a problem in cable television when single ended line amplifiers were required to operate over a broader frequency range. The adopted solution was to use a push-pull circuit configuration which effectively moved the quiescent point to the symmetrical intersection of two transistor transfer curves. With this technique, each transistor was only responsible for amplification of 180° of the stimulus signal and would phase cancel the even harmonic components.

For third order, the remaining transfer function became $Eout=AEin+(BEin)^3$. In the expression, the phase relationship is not periodic at 180° intervals, producing no cancellation of the distortion waveform (Figure 5-6 and 5-7).

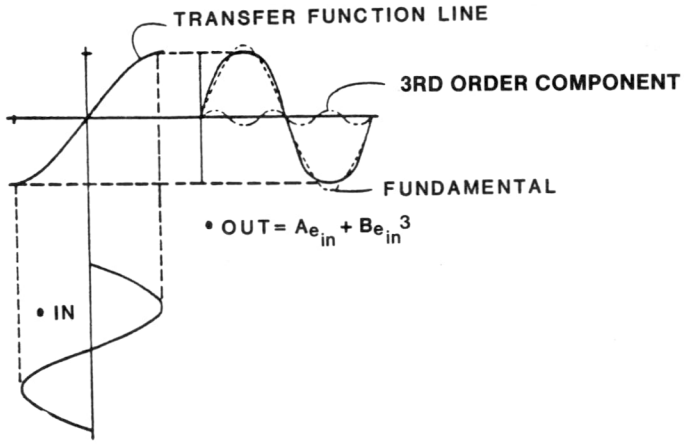


Figure 5-6. 3rd Order Distortion (Time Domain)

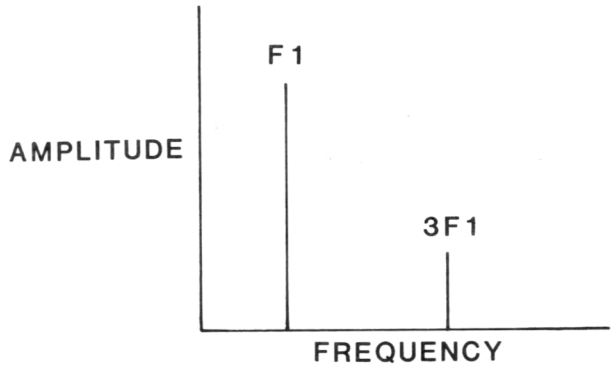


Figure 5-7. 3rd Order Harmonic Distortion (Frequency Domain)

The third order mixing of three fundamental carriers will also pass through this transfer function producing new frequencies predicted by the expression±F1±F2±F3 (Figure 5-8). It is the discrete (single frequency component of these carriers) or the composite summation of multiple trios of frequencies (beats) which produces the relative distortion known for limiting amplifier cascades in heavily loaded CATV systems.

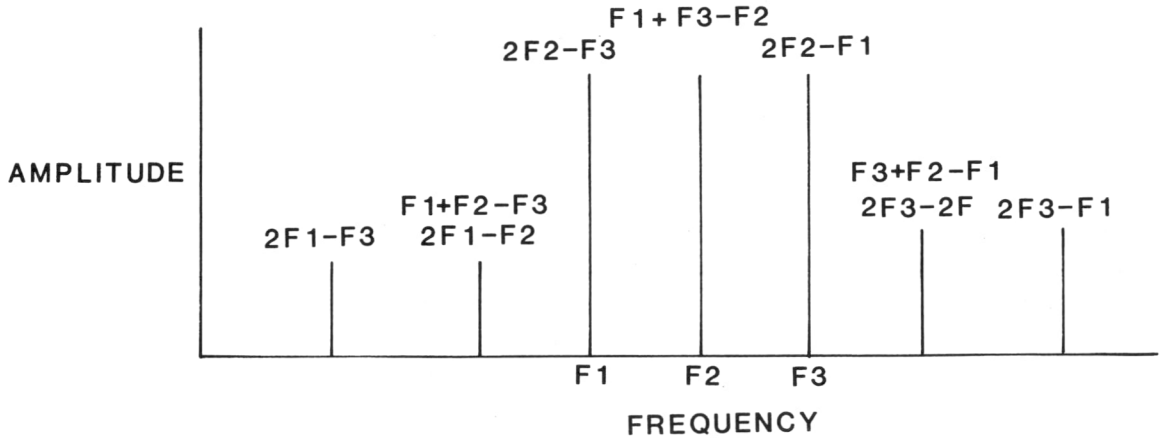


Figure 5-8. Discrete Triple Beat

Advances have been made in third order distortion over the past few years. Feed-forward is an excellent approach to obtain better transfer characteristics (Figure 5-9).

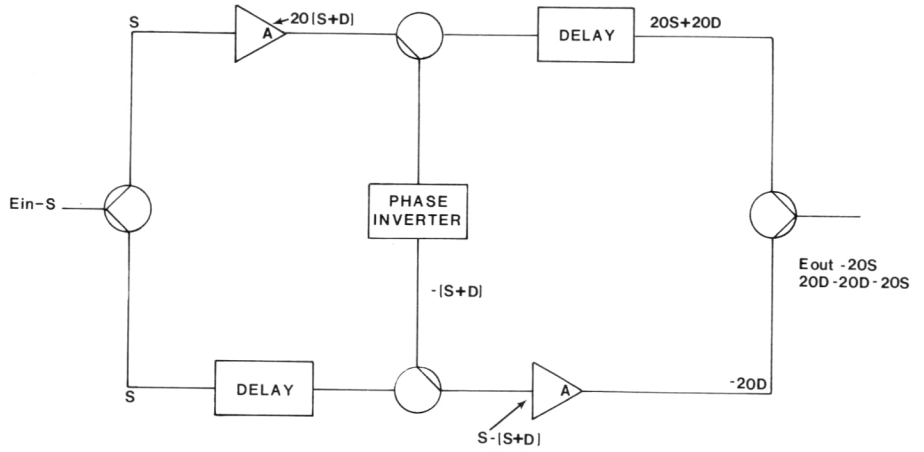


Figure 5-9. Feed Forward Concept

In this approach, the incoming signal is divided into two (2) routes, the signal route and the distortion route. The signal route amplifies the signal and produces distortion, A(S+D). This amplifier output is tapped and supplied to a phase inverter to produce inverted S+D (relative phase delay). This signal is then mixed with the original incoming signal and amplified. The original signal is phase cancelled and the resultant output equals inverted 20D. The distortion amplification path is now combined with the signal amplifications path, the resultant being 20S+20D-20D=20S or gain to the original signal with distortion cancellation.

Testing Concept

The primary concern in intermodulation testing is not the amplitude or power of the beat components, but rather the knowledge of the relative effect the component has on a transmission carrier. The CATV industry typically has evenly spaced carriers with consistant modulation techniques supplying information to a standard receiver. It became apparent that with a fully loaded system it would be easier to interpret a limitation value of "perceived" distortion on a single style of receiver. This brought about "composite beat testing."

The Local Area Network industry may or may not operate with evenly spaced carriers. Their modulation techniques vary with transmission speed and format, and the receive characteristics are dependent upon these modulation schemes.

Yet another dimension which adds to the testing dilemma is the fact that carrier amplitudes vary with loading, modulation format, speed, and spectrum allotment. Second and third order tests are "relative" tests; relating the beat peak or effective amplitude to a specific carrier amplitude. This would lead one to conclude that a measurement relative to one transmission carrier may not apply to another (Figure 5-10).

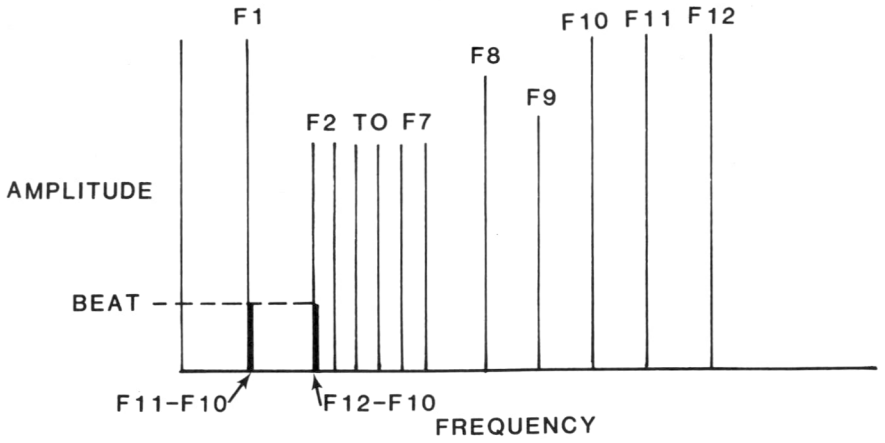


Figure 5-10. Relative Tests

In this example, the second order beat produced by the difference of F11-F10 produces a component which falls around F1. A beat of the same amplitude is also produced by the mixing of F12-F10, resulting in a component at F2's operating frequency. The absolute values of the beat components in this example are the same, but the relative measurements are different. The resultant effect of these beats will most likely be different, entirely dependent upon the individual receiver's distortion threshold.

One conclusion which could be drawn is that the best performance test would be the simulation of the "exact" spectrum loading with C.W. carriers and examine all possibilities. This would yield the greatest understanding in a worst case condition, but would not predict conditions if expansion was desired at a later date. The test set generator to simulate this spectrum would also be extremely expensive, as frequency agility and spectral purity are difficult design tasks in instrumentation. The test scenario would also probably prove impractical, as sheer size and portability would limit its usage.

It is the recommendation of this article that discrete intermodulation testing be used as opposed to composite or other techniques. In this testing approach, two (2) or three (3) carriers are used to produce the desired beat, dependent upon the order of the distortion, with a third or fourth carrier injected as a reference, if needed. The figure derived from this procedure should be used as an operational "figure of merit", relating the environment of the transmission medium to the desired peripheral.

There are many practical advantages to discrete testing. Included in these are:

1. The amplifiers are tested in an elevated output level condition. This will exercise the equipment in an equivalent power handling capacity. The elevated levels produce beats which are also elevated in amplitude. This improves the carrier-to-noise relationship of the distortion component, enhancing the measurement accuracy and repeatability.
2. The correlation between design team predictions and actual tests results will be much closer. This will allow closer inspection of vendor components for compliance.
3. Field troubleshooting using the half and double cascade technique will help uncover single station distortion to shorten down-time. Recorded data from acceptance testing could be available at each amplifier for comparison.

4. Carriers used to create distortion could be used for other system tests, such as hum or carrier-to-noise, when operated at system levels. References would be readily available for spot amplifier inspection or tap energy allotment checks.

Test Equipment:

The test equipment needed for discrete intermodulation measurements include a spectrum analyzer (Wavetek Model 1880 or 1881), a preselector (Wavetek Model PP-75) and a multi-carrier test generator.

Test Procedure:

To perform the second order intermodulation test, inject the test carriers at the point of origin desired. This would typically be the head end for outbound testing and at the furthest amplifier input for return testing. Set the output level of the test generator such that the amplifiers are overdriven but still in the linear relative change area of operation (Figure 5-11).

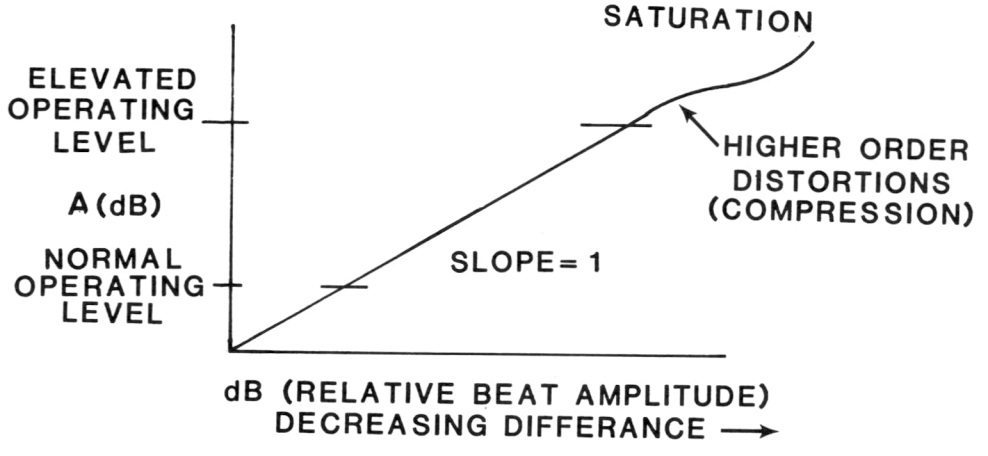


Figure 5-11. 2nd Order Relationship

This curve suggests that amplifiers may be operated at elevated levels (typically 20dB for these carriers) and still produce a linear change relation of one for one. In other terms, a + 1dB change in output level will bring the beat 1dB closer in relative amplitude. This elevated level should be available from the vendor or by inspection. To calculate the level, use the formula:

$$\text{Test level increase (dB)} = 10 \text{ Log } \left(\frac{\text{Maximum Number of System Video Carriers}}{\text{3 Carriers}} \right)$$

To make the measurement, read and record the amplitude of the reference carrier with a properly pre-selected spectrum analyzer (Wavetek Model 1881). Remove the test carrier and remove attenuation on the analyzer until the beat is stable on the display. Record the peak amplitude of the beat. Subtract the beat amplitude from the reference carrier amplitude to obtain the relative difference. Next, add the amount of test level increase to the relative difference. The result is the second order beat measurement at system operating levels.

FORMULA: dB(second order)=(test output level-beat level) + change in levels.

The third order test is performed in the same manner. The main difference is that three test carriers are used instead of two and the relative change difference is two-to-one instead of one-to-one (Figure 5-12).

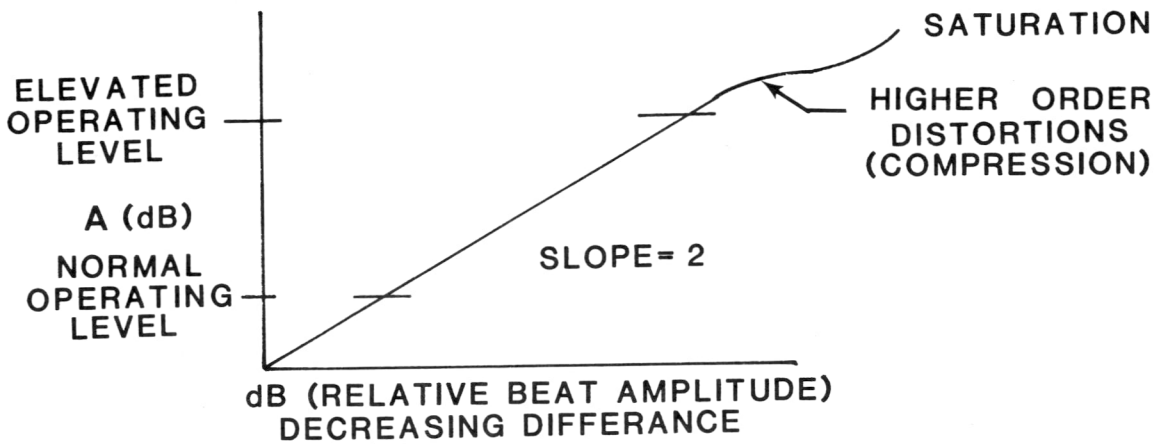


Figure 5-12;. 3rd Order Relationship

FORMULA: dB(third order)=(test output level-beat level)+2(change in levels)

RETURN LOSS

Test Definition:

Return loss is defined as the measurement of a device's ability to pass or dissipate RF energy, relative to the energy reflected back to the source. These reflections are typically caused by improper impedance match characteristics of the component under evaluation. Poor return loss cancels desired transmission energy and may be the cause of standing waves observed while sweeping.

Two forms of return loss testing are usually performed by the system's technician. One, port match, is associated with components in the system, such as directional couplers, splitters, and line amplifiers. The other, structural return loss, is a phenomenon of the transmission cable and should be tested with a slightly different technique.

Test Equipment:

The test equipment generally used to measure return loss consists of a sweep generator (Wavetek Model 1081) and return loss bridge (Wavetek Model FB40-75). A fixed bridge (fixed impedance) is typically used to measure port match and variable impedance/capacitance bridges are used for coaxial cable.

Test Procedure:

To test for port match, connect a sweep generator's (Wavetek Model 1081) RF output to the input port of 75 ohm RF bridge (Wavetek Model FB40-75). The RF bridge will allow the inspection of only the reflected energy from the device under test. Connect the output port of the bridge to the receive or detector input port of the sweeper. See Figure 6-1.

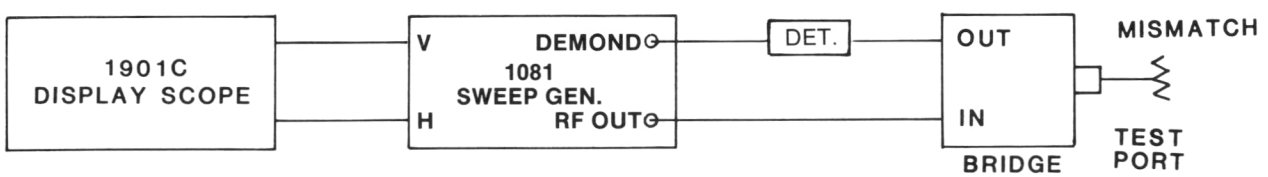


Figure 6-1. Return Loss Test Set-Up

Set the sweep bandwidth to cover the desired operating band and adjust the output level 10dB below maximum.

NOTE: Line amplifiers should be tested at lower levels. Refer to the specific manufacturer's instruction manual for proper level adjustments.

Next, connect a precision mismatch to the bridge test port. This component has been calibrated to have a "known" amount of match and should be used for a CRT calibration line. For line components, a 20dB mismatch should be used. Connect and record the reflection curve with a grease pencil or with the storage capacity of the equipment (Figure 6-2).

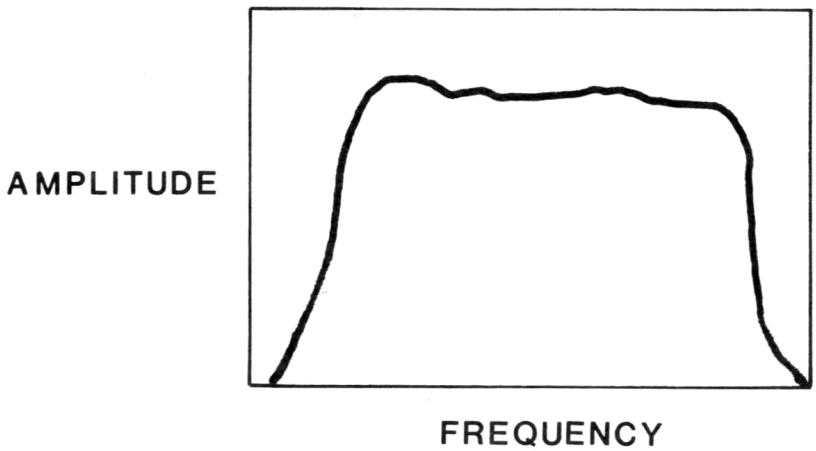


Figure 6-2. Reference Curve

Next, connect the device under test to the bridge and increase the output level until the test curve crosses the reference curve (Figure 6-3).

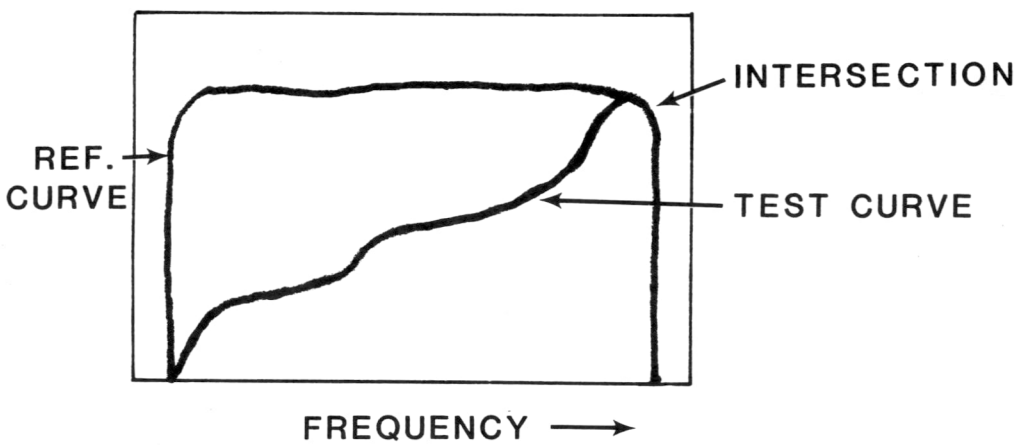


Figure 6-3. Test Curve (with Reference)

Subtract the amount of level increased from the reference line value. The resultant figure is the return loss value of the component.

Example:

Reference	20dB mismatch
Level increase	3.5dB
Return loss	16.5dB

The measurement can be simplified by the use of a comparator (Wavetek Model 1076) with the sweep generator (Wavetek Model 1081). An RF comparator is a test instrument which toggles the sweep between the test device and a set of precision

attenuators, giving the operator a real time reference. Refer to the operating manual for hook-up and operation instructions.

NOTE: When using an RF comparator, be sure to subtract the loss value, typically 12-15dB, of the bridge from the final readings.

TAP ISOLATION

Test Definition:

Broadband multi-tap ports are designed to pass RF energy back and forth from the input connection while attenuating the signal from the output port or other ports. This "isolation" of the port connection secures the terminal device from interference due to reflections or spurious products from a second port operation. See Figure 7-1.

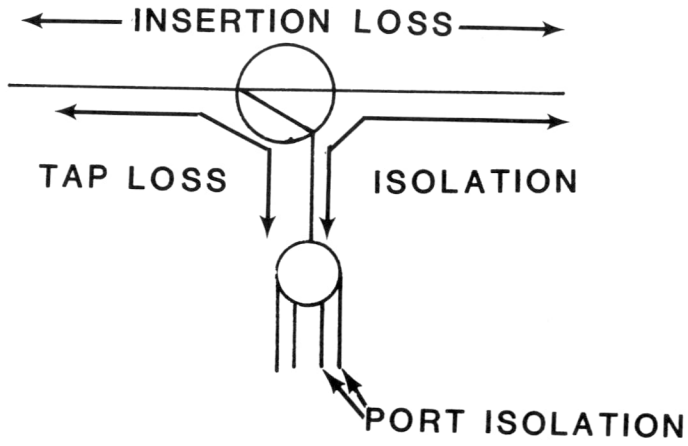


Figure 7-1. Multi-Port Tap

Test Equipment:

Since isolation is typically frequency dependent, it is best to sweep the device with a sweep generator (Wavetek Model 1081) or recovery system (Wavetek Model 1855B/1865B). The instruments used to align and balance the system will typcially give excellent isolation curves.

Test Procedure:

To perform the test, connect the sweep generator to one of the terminal ports. Set the test level of the sweeper to +50dBmV or greater. Terminate all unused ports, except for the port to be tested. Connect the receiver to this port and adjust the input attenuation until the isolation curve clearly deflects the CRT and is free of noise. See Figure 7-2.

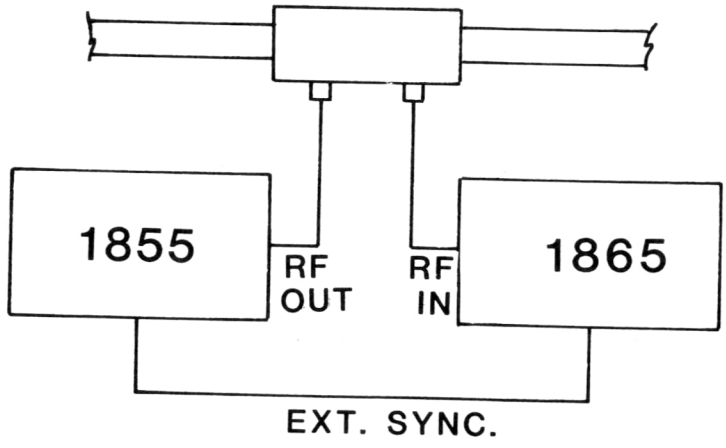


Figure 7-2. Isolation Test Set-Up

The test results will typically be very good at low frequencies and become worse at high frequencies in somewhat irregular patterns. See Figure 7-3.

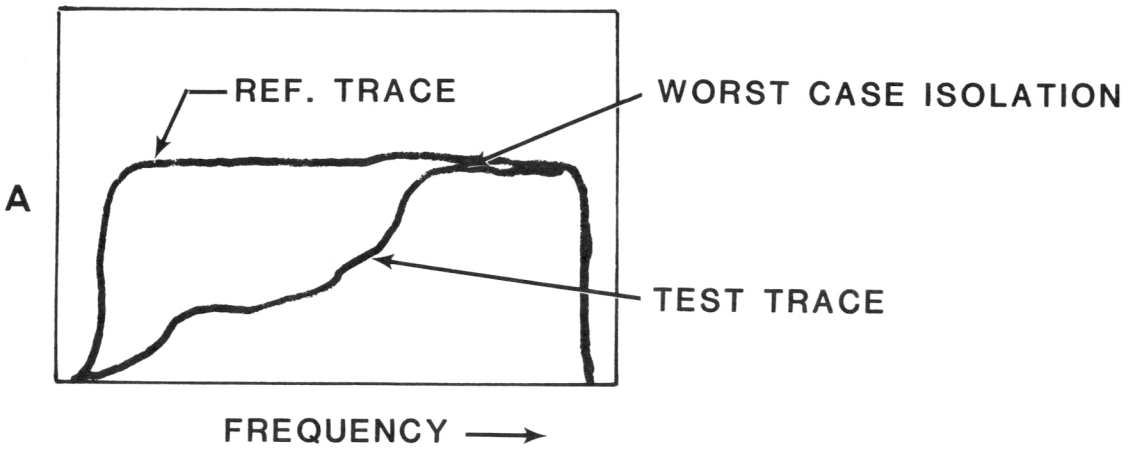


Figure 7-3. Test Results

Record the highest level of received energy and subtract this level from the output level of the generator. The ratio, in dB, between the sweep input level and the worst case receiver level is the tap isolation figure. If the measurement is performed on the bench, the line isolation should also be checked. See Figure 7-4.

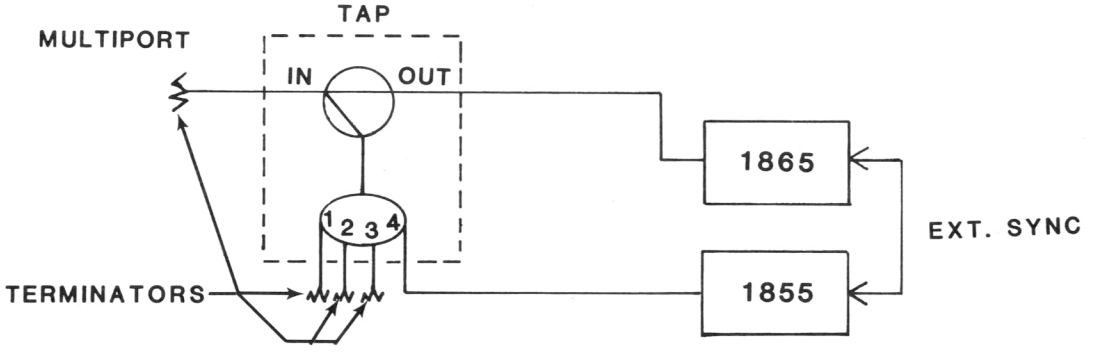


Figure 7-4. Line Isolation Test Set-Up

The technique for this test is identical to the port test defined earlier.

LEAKAGE

Test Definition:

Radio frequency leakage is defined as the loss of energy into free space due to improper "sealing" of the coaxial system. This radiation has the potential to interfere with licensed broadcast signals, aircraft navigation aids, and other forms of communication equipment. The reciprocal of this condition is the potential for high-powered "off-air" signals to interfere with proper systems performance. Well maintained LANs should have a preventive maintenance program which:

1. Monitors for the loss of high-level energy, such as data carriers or leakage "beacons".
2. Monitors for the ingress of local broadcast frequencies, such as low and high band VHF and FM signals.
3. Regularly measures "absolute levels" of system leakage.

This policy will guard against untimely shut-downs due to carrier ingress or legally stimulated leakage evaluations.

The most common form of leakage testing is radiation monitoring with a transmitter and narrow band receiver. This technique is inexpensive to implement and assures the greatest system coverage. The concept calls for a tone modulated test carrier to be inserted at the headend and the system wide patrolling with sensitive receivers for the egress of this signal. Potential system problems, such as loose fittings or broken cables, can be found before they become a major system failure source.

Test Equipment:

The test equipment needed for leakage monitoring include the CR-6 receiver and a signal generator capable of 700 Hz - 1 KHz sine wave modulation (Model 3000 signal generator).

For leakage measurements, the Wavetek Model RD-1 dipole antenna and a Wavetek Model SAM III signal meter will have sufficient sensitivity.

Test Procedure:

Egress Monitoring:

To implement a leakage monitoring test, insert the tone modulated carrier, at

system levels, into the headend. This signal should be left on to enable a continuous reference for leakage monitoring. With the CR-6 tuned to receive this test signal, hand carry the unit throughout the system. Squelch breaks should be investigated using the locator "beacon" provided with the CR-6.

Egress Measurement:

The radiation levels to be measured are typically in the -30 to -50dBmV range. Since most signal level meters do not operate well at these levels, the RD-1 is useful in that it detects the radiation and amplifies it to a level within the range of the signal level meter. Select the frequency to be checked and set the dipole whips to the correct length. (Field tests have shown that the exact length is not critical, but care should be taken to be as accurate as possible when setting the dipole length.) Place the RD-1 such that the dipole is 10 feet away from the cable and parallel to the cable. The reading on the signal level meter can then be compared to the maximum signal level meter reading permissible under the FCC specification (20uV/m at 10 feet).

Ingress Measurement:

With a spectrum analyzer (Wavetek Model 1880 or 1881) connected to a system test point, examine all known "off-air" frequencies for system ingress. Levels should be recorded for reference at a later date. Excessive off-air levels are an indicator of ingress/egress and should be investigated to find the source.

RECOMMENDED WAVETEK TEST EQUIPMENT

FOR SYSTEM FREQUENCY RESPONSE TESTING:

TD-1 — PORTABLE, BATTERY POWERED CONTINUOUS SWEEP GENERATOR. With 4-450 MHz fixed frequency range and adjustable output level from 0 to +10dBmV, or +20 to +30dBmV.

1801C — SWEEP GENERATOR. 1 to 1000MHz laboratory type sweep generator. Output continuously adjustable from +57 to -33dBmV. Recurring, single sweep, external trigger, manual, and linelock sweep modes. Continuously variable sweep time and repetition interval.

1881 — SYSTEM ANALYZER. 4 to 1000MHz with same features as 1880, enhanced with improved carrier-to-noise measurement capability, non-volatile storage of channel parameters and leakage monitor function. 20dB pre-amp and 3 fixed frequency preselectors built-in (specify frequencies when ordering, 54-450 range). BC-3A heavy duty battery charger included.

1855B — SWEEP TRANSMITTER. 1 to 450MHz (400MHz max span) microprocessor controlled sweep transmitter with variable sweep width, level, rate, and repetition interval.

1865B — SWEEP RECEIVER. Microprocessor controlled sweep receiver. Keyboard operation, digitally generated raster scan display with alpha-numberic readout of information pertinent to displayed sweep response.

C-1 — CAMERA. Polaroid camera for display pictures (for use with 1880, 1881, 1865B).

FOR GROUP DELAY TESTING:

4501/4602 — GROUP DELAY ANALYZER and DISPLAY OSCILLOSCOPE. 5 to 1500 MHz group delay analyzer, uses swept frequency techniques to read group delay by meauring phase shift of modulating envelope of an amplitude modulated RF carrier as it passes through device under test.

1080 — SWEEP GENERATOR. 1 to 1000MHz sweep generator. Digital display of frequency and output level. CW, Delta F, and full sweep

modes. Continuously variable sweep width (Delta F mode), and output level, from +13 to -70dBm. 100, 10, and 1MHz harmonic markers (Delta F), and variable pinball marker (full sweep) included.

PA-20 — AMPLIFIER. Battery powered general purpose 20dB low noise amplifier (50-250MHz).

7580 — ATTENUATOR. 75 ohm attenuator, 0 to 80dB in 1.0dB steps (0-1000MHz).

FOR CARRIER-TO-NOISE TESTING:

SAM I — SIGNAL LEVEL METER. 4 to 450MHz full performance meter with built-in calibrator, volt meter, carrier-to-noise, hum, and spectrum analyzer for X-Y display scope.

SAM III — SIGNAL LEVEL METER. 4 to 450MHz microprocessor controlled meter, keyboard and manual tuning, LCD frequency display, built-in calibrator, volt meter, carrier-to-noise, hum, and spectrum analyzer interface for X-Y display scope.

SAM IIID — SIGNAL LEVEL METER. SAM III with RS232 interface for remote operation.

SAM IVDX — SIGNAL LEVEL METER. 4 to 450MHz microprocessor controlled head-end rack mount meter with built in spectrum analyzer display, keyboard and manual tuning, LCD frequency display, built-in calibrator, volt meter, carrier to noise and hum. Enhancements for remote operation include RS232 interface and built-in phone modem.

1880 — SYSTEM ANALYZER. 4 to 450MHz microprocessor controlled system analyzer with keyboard control and digitally generated raster scan display. Automated test functions of carrier-to-noise, hum, FM deviation, cross modulation, and 2nd/3rd order (composite triple beat).

1881 — SYSTEM ANALYZER. 4 to 1000MHz with same features as 1880, enhanced with improved carrier-to-noise measurement capability, non-volatile storage of channel parameters and leakage monitor function. 20dB pre-amp and 3 fixed frequency preselectors built-in (specify frequencies when ordering 54-450 range). BC-3A heavy duty battery charger included.

FOR HUM MODULATION TESTING:

SAM I — SIGNAL LEVEL METER. 4 to 450MHz full performance meter with built-in calibrator, volt meter, carrier-to-noise, hum, spectrum analyzer for X-Y display scope.

SAM III — SIGNAL LEVEL METER. 4 to 450MHz microprocessor controlled meter, keyboard and manual tuning, LCD frequency display, built-in calibrator, volt meter, carrier-to-noise, hum, and spectrum analyzer interface for X-Y display scope.

SAM IIID — SIGNAL LEVEL METER. SAM III with RS232 interface for remote operation.

SAM IVDX — SIGNAL LEVEL METER. 4 to 450MHz microprocessor controlled head-end rack mount meter with built in spectrum analyzer display, keyboard and manual tuning, LCD frequency display, built-in calibrator, volt meter, carrier to noise and hum. Enhancements for remote operation include RS232 interface and built-in phone modem.

FOR INTERMODULATION TESTING:

1880 — SYSTEM ANALYZER. 4 to 450MHz microprocessor controlled system analyzer with keyboard control and digitally generated raster scan display. Automated test functions of carrier-to-noise, HUM, FM deviation, cross modulation, and 2nd/3rd order (composite triple beat). BC-3A heavy duty battery charger included.

1881 — SYSTEM ANALYZER. 4 to 1000MHz with same features as 1880, enhanced with improved carrier-to-noise measurement capability, non-volatile storage of channel parameters and leakage monitor function. 20dB pre-amp and 3 fixed frequency preselectors built-in (specify frequencies when ordering, 54-450 range) BC-3A heavy duty battery charger included.

PP-75 — PRESELECTOR. Tunable precision preselector, combining three separate preselectors in one field portable housing (55-110MHz, 110-220MHz, and 220-440MHz).

FOR RETURN LOSS TESTING

1081 — SWEEP GENERATOR. 1 to 1000MHz sweep generator. Digital display of frequency and output level. CW, Delta F, and full sweep modes. Continuously variable sweep width (delta F mode), and output level, from +60 to -10dBmV. 100, 10 and 1 MHz harmonic markers (delta F), and variable pinball marker (full sweep) included.

1076 — SWEEP COMPARATOR. 1 to 1000MHz sweep comparator. Detector output may be shaped to provide logarithmic or quasilinear response. Built-in RF post amplifier.

1091C — DISPLAY OSCILLOSCOPE. 12 inch X-Y display oscilloscope designed for sweep response display. Marker adder produces pinball (bright spot) markers from birdy or pulse marker input. Automatic blanking when horizontal input is removed.

FB40-75 RETURN LOSS BRIDGE. Precision BNC to F type adaptors, calibrated 75 ohm termination, and protective carrying case included.

FOR TAP ISOLATION TESTING:

1855B SWEEP TRANSMITTER. 1 to 450MHz (400MHz max span) microprocessor controlled sweep transmitter with variable sweep width, level, rate, and repetition interval.

1865B SWEEP RECEIVER. Microprocessor controlled sweep receiver. Keyboard operation, digitally generated raster scan display with alpha-numeric readout of information pertinent to displayed sweep response.

1081 SWEEP GENERATOR. 1 to 1000MHz sweep generator. Digital display of frequency and output level. CW, Delta F, and full sweep modes. Continuously variable sweep width (delta F mode), and output level, from +60 to -10dBmV. 100, 10 and 1MHz harmonic markers (delta F), and variable pinball marker (full sweep) included.

1901C DISPLAY OSCILLOSCOPE. 12 inch X-Y display oscilloscope designed for sweep response display. Marker adder produces pinball (bright spot) markers from birdy or pulse marker input. Automatic blanking when horizontal input is removed.

1076 SWEEP COMPARATOR. 1 to 1000MHz sweep comparator. Detector output may be shaped to provide logarithmic or quasilinear response. Built-in RF post amplifier.

FOR LEAKAGE TESTING:

CR-6 SIGNAL RECEIVER. High sensitivity scanning receiver crystalled to receive 6 video carrier frequencies on the cable system. Locator tone varies in pitch with strength of detected signal. Lock out switch to eliminate off-air interference. Standard channels 2, 3, 4, D, G, R. Consult factory for other frequencies.

3000 SIGNAL GENERATOR. 1 to 520MHz signal generator with 1kHz resolution. High stability signals accurate to 0.001%.

RD-1 DIPOLE ANTENNA. Tunable dipole antenna for use in measurement of detected leaks. 16dB battery operated amplifier built-in.

SAM III SIGNAL LEVEL METER. 4 to 450MHz microprocessor controlled meter, keyboard and manual tuning, LCD frequency display (built-in calibrator, volt meter, carrier to noise, HUM, and spectrum analyzer interface for x-y display scope). SAM bag included.

1880 SYSTEM ANALYZER. 4 to 450MHz microprocessor controlled system analyzer with keyboard control and digitally generated

raster scan display. Automated test functions of carrier-to-noise, HUM, FM deviation, cross modulation, and 2nd/3rd order (composite triple beat). BC-3A heavy duty battery charger included.

1881 SYSTEM ANALYZER. 4 to 1000MHz with same features as 1880, enhanced with improved carrier-to-noise measurement capability, non-volatile storage of channel parameters and leakage monitor function. 20dB pre-amp and 3 fixed frequency preselectors built-in (specify frequencies when ordering, 54-450 range) BC-3A heavy duty battery charger included.

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